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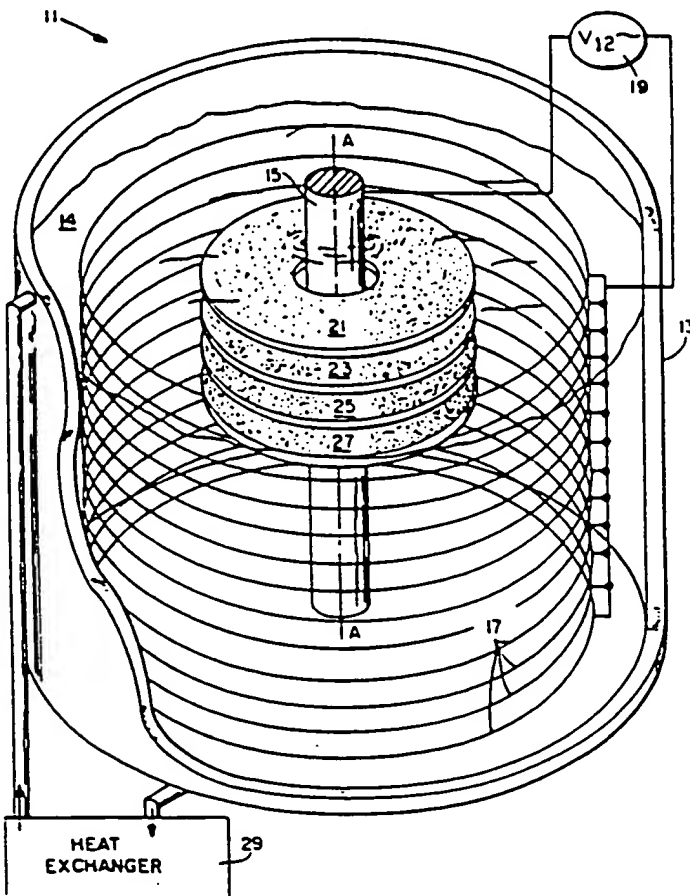
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(54) Title: DEUTERIUM ACCUMULATOR FOR ENERGY CONVERSION

(57) Abstract

Method and apparatus (11) promoting electrolyte ionization of high purity heavy water (containing  $\text{Li}^6\text{OD}$ ), thereby producing deuterium ions and lithium ions that are accelerated by an alternating voltage. These are swept through a matrix (31) of suspended deuterium-absorbing and lithium-absorbing particulates (35) and collected in the interior of said particulates. The electrodes (17, 15) are spaced apart and immersed in the liquid (14) with an alternating voltage between them. The matrix of suspended particulates is located between the two electrodes. When the deuterium and lithium ions pass through the particle matrix, a fraction of the ions strike the particulates and are absorbed into them. The deuterium and lithium ions which are absorbed in the particulates may fuse or otherwise combine or produce heat energy.



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## Description

### Deuterium Accumulator for Energy Conversion

#### 5 Technical Field

This invention relates to a cell for production of thermal energy by conversion from other forms of energy.

#### 10 Background Art

Electrically charged particles such as bare electrons or protons or muons are known to be Fermions and to obey Fermi-Dirac statistics. Two like elementary charged particles, such as two protons, have like electrical charges so that they tend to repel one another. Further, two like Fermions obey the Pauli exclusion principle so that, if the particles possess identical quantum numbers, the two identical particles will not occupy the same region of space at the same time, even if the identical particles have no net electrical charge. The combination of two Fermions in a nucleus, such as a neutron and a proton, which together form the nucleus of a deuterium atom or ion, behaves as another type of particle, called a Boson, which obeys Bose-Einstein statistics rather than Fermi-Dirac statistics. This has been discussed recently by K. Birgitta Whaley, a theoretical chemist speaking at the Dallas meeting of the American Chemical Society in April, 1989.

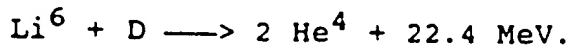
Particles that obey Bose-Einstein statistics ("Bosons") tend to accumulate in the same region of space under some circumstances, in preference to staying apart as like Fermions tend to do. This tendency of Bosons to accumulate in the same region of space is indicated by a quantum thermodynamic expression for the pressure in a system of Bosons developed and discussed in Statistical Physics by L.D. Landau and E.M. Lifshitz, Addison-Wesley Co., 1958, p. 159. In this expression for pressure, the pressure developed by a system of Bosons is less than the

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pressure developed by a system of particles that are neither Fermions nor Bosons at the same concentration and temperature. This suggests that the Boson particles experience a modest attraction for one another that has its  
5 origin in quantum mechanical forces.

Whaley has speculated that, because of the quantum effect features of particles such as deuterium nuclei, the natural repulsion between two such nuclei can be blocked inside a crystal so that the deuterium ions  
10 are not held apart by the combination of strong coulomb forces and quantum forces. Some workers speculate that, because deuterium nuclei might be brought very close together inside a crystal, the deuterium nuclei could combine in a fusion process at enhanced rates, as compared  
15 to the infinitesimal rates observed at ordinary fluid densities for deuterium nuclei.

Lithium ions have been widely used in the electrolyte added to heavy water in certain experiments involving palladium by Pons and Fleischmann and many other  
20 researchers. The electrolyte used most commonly is LiOD, wherein most or all of the hydrogen in LiOH is replaced by deuterium. Most reports of generation of heat by these experiments indicated that the LiOD electrolyte had been used. In March, 1990, several physicists speculated  
25 that the excess enthalpy generated may come from the reaction



The excess energy of 22.4 MeV is carried by the kinetic energy of the two helium nuclei, and is dissipated in the  
30 host lattice used, which is usually palladium.

It is known that lithium reacts with hydrogen to form LiH, in which the hydrogen acts as a negative ion. This is evidenced by the fact that when this substance is electrolyzed the hydrogen is liberated at the  
35 anode. Therefore, it would be expected that the close proximity of lithium-6 ions and deuterium ions within the palladium lattice could lead to a strong chemical bond with the deuterium ions being negative and lithium-6 ions

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being positive. In contrast, in the case of two deuterons the coulomb force tends to push them apart.

It is known that some metals will readily accept substantial amounts of hydrogen or its isotopes into the interior of such metals and that such metals can be used to filter hydrogen isotopes from a stream of other substances. In U.S. Pat. No. 4,774,065, granted September 27, 1988 to R. Penzhorne et al., it is disclosed that a hot palladium membrane will filter tritium and deuterium from CO molecules. The palladium membrane disclosed by Penzhorne et al. was used to filter exhaust gas from a fusion reactor.

However, even where a metal such as palladium is chosen as an accumulation structure ("accumulator") for deuterium ions ("deuterons") or lithium ions ("lithons"), those deuterium ions or lithium ions that pick up electrons or other negatively charged particles at the accumulator will no longer behave as Bosons and may not manifest the desirable feature of high density accumulation within the palladium interior or lattice unless they separate from the negative charge and return to positive ions within the lattice. Also, the lithons that pick up an electron at the palladium cathode in the prior art can deposit as lithium atoms on the palladium which can interfere with the fusion process.

One object of this invention is to provide an apparatus that encourages a nuclear reaction within a deuterated palladium lattice to generate excess thermal energy.

Another object of this invention is to provide apparatus that suppresses the tendency of the deuterium ions and lithium ions to pick up electrons as the ions approach the accumulator or as they enter the interior of the metal that serves as the accumulator.

Another object of the invention is to suppress the electrolysis process, which produces unwanted deuterium and oxygen gas, consumes energy, and creates bubbles that disrupt ion flow.

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Another object is to greatly increase the surface area of the accumulation structure to increase the rate at which the fusion process may proceed.

Another object is to provide for electrical  
5 charge neutralization so that absorption or adsorption of positively charged deuterium ions and lithium ions on or within the accumulator will not cause later-arriving deuterium ions to be repelled from this structure.

#### 10 Summary of the Invention

These objects are met by apparatus that enhances deutron and lithon formation in a liquid containing primarily high purity heavy water in which most of the hydrogen ions found in ordinary water are replaced by  
15 ions of the hydrogen isotope deuterium. An LiOD electrolyte containing a substantial amount of lithium-6 is added to ensure significant deutron and lithon formation of the heavy water. The apparatus includes a first and second electrode, each being spaced apart from the other  
20 and being electrically insulated from the liquid in which they are immersed by means of an insulating coating on the electrodes. Alternatively, the electrodes are not insulated from the liquid, but are connected to an alternating voltage source through a large capacitor in one  
25 variation and directly to the voltage source in another variation. The voltage between the two electrodes is sequentially switched from positive to negative and back again as with a square wave or sine wave. An ion accumulator is placed in the liquid between the first and sec-  
30 ond electrode and the accumulator is electrically floating; that is, the accumulator is isolated from the voltage source on the first and second electrodes, except for the electrical conductivity of the liquid. This accumulator comprises a three-dimensional matrix of suspended  
35 particulates, each of which has a surface layer of metal that readily absorbs deuterons and lithons into its interior, or the accumulator particulates may be composed entirely of such material. Examples of such a metal are

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palladium and titanium, where palladium is preferred for excess power generation and titanium may be preferred for tritium production.

In order to move toward the instantaneous negative electrode, most of the positively charged deuterons and lithons produced by use of the electrolyte must pass through the accumulator. With a suitable choice of particulate distribution within a three-dimensional matrix, a fraction of the deuterons and lithons that approach the accumulator will be pulled into the interior of the accumulator material, where the ions can combine and contribute to the production of energy therein. The apparatus promoting ion motion here includes the first and second electrodes whose sequential voltage switching cause the ions to move back and forth through the accumulator particulate matrix. The accumulator attraction to deuterons and lithons is not diminished by accumulation of the deuterium gas and atoms as in the prior art. A fraction of the deuterons and lithons are intercepted and absorbed by the palladium accumulator material each time the ions pass through the accumulator. Within the accumulator material, the deuterons and lithons may act as Bosons and may fuse or otherwise combine to produce heat. The accumulator includes a distribution of particulates of palladium or palladium composites suspended in a three-dimensional matrix. There are a number of ways to accomplish this.

For example, a cylindrically shaped first electrode may surround a rod-like second electrode, with the rod longitudinal axis being approximately parallel to the axis of the first electrode cylinder. A plurality of sheets of material such as planar disks, which are not electrically conductive, is immersed in the liquid at positions between the two electrodes, with each sheet having a surface layer that includes an electrically non-conductive matrix and particulates of a deuterium-absorbing metal such as palladium suspended in it. The sheets are approximately parallel to and spaced apart

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from each other, are spaced apart from a first electrode, and are adjacent to and surround a plane of material in a second electrode. For example, the plurality of sheets may be a group of approximately planar disks, with each disk surrounding a rod-like second electrode and with the plane of each disk being oriented approximately perpendicular to the longitudinal axis of the second electrode. The surface of each sheet is covered with a material that includes metal particulates of a material that absorbs both deuterons and lithons such as palladium. The deuteron and lithon absorbing metal particulates (hereinafter called "metallites") may be suspended in a gelatin-like matrix material such as photographic gelatin derived from cattle bones or nonorganic gelatin derived from polyvinyl alcohol, where this material is typically between 10  $\mu\text{m}$  and 1,000  $\mu\text{m}$  thick, although greater thicknesses are possible. Alternatively, the metallites may be mounted at the surface of a solid dielectric, plastic, ceramic or other similar material so that at least one surface of each of the surface-mounted metallites is exposed directly to deuterium ions in the liquid. In either alternative, the plurality of sheets is positioned so that a charged particle that is initially positioned adjacent to the first electrode must pass adjacent to at least one of the plurality of sheets in order to reach the second electrode. In another embodiment, two electrodes are simply spaced apart, with the plurality of sheets being positioned between the two electrodes. Although the separated metallites are electrically conducting, each sheet taken as a whole is not electrically conducting. Each sheet should, therefore, not significantly alter the electrical field in the liquid that would be present without these sheets. In general, any electrically non-conducting matrix may be used to hold the palladium particulates provided it permits the deuterons and lithons to pass through.

Where separation and ionization occurs and deuterium ions  $\text{D}^+$  and  $\text{OD}^-$  are each produced from a heavy

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water molecule, a deuteron will become accelerated by the electrical field produced by the electrodes and may strike and penetrate one of the metallites so that the metallite acquires an electrical charge of +1. Alternatively, a lithium ion  $\text{Li}^+$  and a deuterium-containing ion such as  $\text{OD}^-$ , are produced by the ionization and a single lithium ion becomes accelerated by the electrical field and strikes and penetrates one of the metallites. Following this event, one of the negatively charged  $\text{OD}^-$  ions will become attracted by and attached to the positively charged metallite so that the metallite now acquires an electrical charge of 0. Following this event, if the metallite has an electrical charge of 0, a second positively charged deuterium ion or lithon may strike the metallite so that the electrical charge on the metallite again becomes positive. The deuterium ions and lithium ions thus become attached to the same metallite, but not necessarily to one another. By this means the palladium metallites become deuterated and may be referred to as  $\beta$  palladium. This process may take place in the cell, or the metallites may be precharged in another cell first. At least 65% of the interstitial sites in the  $\beta$  palladium should be filled with deuterons, and preferably about 85%. Since the solution also contains lithium-6 ions from the ionization of  $\text{LiOD}$ , lithons will also strike the metallites. The lithium-6 ions are Bosons and the deuterium ions are Bosons. Thus, they need not satisfy the Pauli exclusion principle inside the palladium lattice. Therefore, these ions can come very close together and may fuse within the lattice. When the deuterons and lithons in the metallite fuse thermal energy is generated which is removed by the liquid. An external heat exchanger captures this energy.

### Brief Description of the Drawings

Fig. 1 is a perspective cutaway view of a first embodiment of the invention.

Fig. 2 illustrates several suitable forms for a time-varying voltage difference imposed between two electrodes in Figs. 1, 4, 5, 6 and 7 according to the invention.

5           Fig. 3 is a side view of one of the sheets in Fig. 1 for the first embodiment of the invention.

Fig. 4 is a cutaway side view of surface-mounted metallites according to a second embodiment of the invention.

10           Figs. 5, 6 and 7 are perspective cutaway views of other embodiments of the invention.

Fig. 5a is an enlarged view of a portion of an open mesh cylinder used in the embodiment of Fig. 5.

15           Fig. 6a is an enlarged view of a portion of a rod surface used on the embodiment of Fig. 6.

#### Best Mode for Carrying Out the Invention

With reference to Figure 1, the apparatus 11 in one embodiment includes a container 13 containing a  
20 liquid 14 that contains substantial amounts of high purity heavy water  $D_2O$  and an amount of  $LiOD$  electrolyte in a concentration of between  $0.1M$  and  $1.0M$ , preferably closer to  $0.1M$ , to ionize and create a large ion population and an increase in electrical conductivity of the liquid. It  
25 is important that the  $LiOD$  contains at least seven percent of lithium-6 with the remainder being lithium-7. A higher percentage of lithium-6 is preferred. An electrically insulated electrode 15 and a second electrically insulated electrode 17 are immersed in the liquid and  
30 spaced apart from each other and are connected by a voltage source 19, that imposes a time-varying electrical voltage  $V_{12}(t)$  on the first electrode 15 relative to the electrical voltage of the second electrode 17. The  $D_2O$  molecules in the liquid 14 are partly decomposed, by ac-  
35 tion of the electrolyte, into negative ions  $OD^-$ , which are drawn toward the second electrode 17, when a positive voltage appears there, and positively charged deuterons  $D^+$  and lithons  $Li^+$ , which are drawn toward the first

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electrode 15, when a negative voltage appears there. When the voltage difference is reversed in sign, negative and positive ions are drawn to the second and first electrodes 17 and 15, respectively. The first electrode 15  
5 may be a rod-like, electrically conducting material, coated with an insulator such as varnish, glass, plastic or ceramic, that has a longitudinal axis AA oriented as shown in Figure 1. The second electrode 17 radially surrounds the first electrode 15, is also composed of electrically conducting material and coated with an insula-  
10 tor, and may be formed as a helix, as a collection of approximately concentric rings, or as an open mesh cylindrical surface that contains certain openings, or as a tube with or without apertures.

15 The insulators coating electrodes 15 and 17 each create an electrical capacitor with one conductor being, for example, electrode 15, and the other conductor being the ionized liquid. A thin metal coating, preferably gold, silver or platinum may optionally coat the in-  
20 sulator to form a more obvious capacitor. If a low frequency voltage is applied across electrodes 15 and 17, most of the voltage would drop across the high impedance capacitance at 15 and at 17 and very little voltage drop would occur across the low impedance ionized liquid.

25 Optionally, external capacitors may be connected in parallel with the capacitance at 15 and 17 to reduce the voltage drop across the insulator coating. Alternatively, the electrodes are not insulated from the liquid, but are connected to an alternative voltage source through a  
30 large capacitor to minimize the impedance in series with the liquid. Preferably such electrodes are covered with gold, silver or platinum.

The rod-like first electrode 15 is surrounded by a plurality of adjacent sheets or planar disks, several of which are shown as 21, 23, 25, 27, that are spaced  
35 apart from each other, from the second electrode 17 and from the first electrode 15. The second electrode 17, which may be coaxial with or radially surround the first

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electrode 15, may be a helical wire wrapped about an open insulative form, may be a tubular member with or without apertures therein, may be a plurality of electrically connected rings, or may be a mesh cage configuration.

5 Each sheet 21, 23, 25, 27 is oriented approximately parallel to each of the other sheets, and each sheet has a surface layer on one or both sides that includes a gelatin-like, electrically non-conductive matrix in which metallites are suspended. The gelatin-like substance may  
10 be any of organic gelatin derived from cattle bones or nonorganic gelatin derived from polyvinyl alcohol and may have a thickness typically between 10  $\mu\text{m}$  and 1000  $\mu\text{m}$ . Greater thicknesses are also feasible. The matrix itself should be permeable to deuterons and lithons, and possi-  
15 bly to  $\text{OD}^-$  ions, so that the deuterons and lithons may easily move through the gelatin-like matrix to reach the submerged or exposed surfaces of all the metallites contained in the matrix. This composite structure will be referred to as a deuteron/lithon accumulator. Alterna-  
20 tively, the metallites may be surface mounted on sheets 21, 23, 25 and 27 in Fig. 1, as shown in Figs. 4, 5a and 6a. The apparatus may include a heat exchanger device 29 associated with the metallites for conversion or accumu-  
lation of thermal energy produced in such metallites.

25 Fig. 2a, 2b and 2c illustrate a variety of time-varying voltages that are suitable for the voltage difference  $V_{12}(t)$  imposed by the voltage source 19 between the first and second electrodes 15 and 17. These voltages include, but are not limited to: (a) rectangular  
30 wave; (b) trapezoidal; (c) triangular; (d) sawtooth; and (e) sinusoidal. The voltage difference  $V_{12}(t)$  should be positive for one fraction of the time and negative for a second fraction of the time, but these two fractions need not be equal. The voltage difference  $V_{12}(t)$  may also be  
35 approximately zero for a third fraction of the time. The peak positive and negative values of  $V_{12}(t)$  need not have the same magnitude. Where the voltage difference  $V_{12}(t)$  is alternately positive and negative during

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different time intervals, the positively charged deuterons  $D^+$  and lithons  $Li^+$  will be swept through the accumulator toward the second electrode 17 and toward the first electrode 15 during these different time intervals. A portion of these ions will thereby become adsorbed on or absorbed within the surface layer of the accumulator with each sweep through of these ions.

Fig. 3 illustrates one of the sheets 21, 23, 25, 27 from Fig. 1 in a side view, showing a surface layer including an electrically non-conducting gelatin-like matrix 31 of a certain thickness  $d_2$  that is mounted on a structural substrate 33 of an electrically nonconducting material that provides support for the matrix but has only a minor effect on the local electrical field. A plurality of particulates 35 of deuterium-permeable metal are distributed throughout the matrix 31, as a part of the surface layer. The diameters  $d_1$  of the particulates or metallites are preferably less than the thickness  $d_2$  of the matrix layer 31. The matrix may be mounted on both sides of an electrically non-conducting substrate 33, as shown in Fig. 3, or on one side of the substrate.

The metal, which must absorb both deuterons and lithons is preferably palladium or palladium composites, and the representative diameter  $d_1$  of the particulates may be from 0.005 mm to 10 mm. and larger, particularly when the metallites are surface mounted. The volume fraction of metallites in the surface layer may be between 10 percent and 90 percent. The surface layers of the sheets 21, 23, 25, 27 form an accumulation structure for the deuterons and lithons that are present through electrolyte-induced ionization of the liquid 14.

Under some circumstances, the metal particulates or metallites can accumulate deuterons and lithons more efficiently than a continuous structure of the deuterium/lithium permeable metal or an electrode of the metal. By dispersing a large number of metallite particles in the matrix 31, the total surface area of this collection of particles, relative to the surface area of

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the matrix volume, may be made very large, by making the particle diameters smaller and smaller. Metallites permit the use of more than one type of deuterium permeable materials to be used in the same apparatus. That is, 5 metallites might be chosen from two or more metals if other metals or composites matching the performance of palladium are found.

Consider a collection of deuterons and OD ions that have been produced by electrolyte-induced ionization within the liquid. A deuteron  $D^+$  senses the presence of 10 the instantaneous negative voltage electrode and moves toward that electrode. In doing so, the deuteron must pass adjacent to a surface layer of one or more of the sheets 21, 23, 25, 27, and the passing deuteron may become adsorbed on or absorbed within one of the metallites 15 in the surface layer of that sheet. The metallite that has absorbed the deuteron then acquires an electrical charge of +1 and can attract an adjacent negatively charged  $OD^-$  ion to its surface. If the  $OD^-$  ion, having 20 an electrical charge of -1, is attracted to the surface of the metallite, the net electrical charge of the metallite becomes zero. Lithon accumulation would occur in the same manner. The deuterons and lithons attracted to the metallite can easily pass into the interior of the 25 metallite, but  $OD^-$  ions will generally remain on or adjacent to the surface of the metallite. The steps of attraction of positively charged deuterons, which are absorbed by the metallite, and negatively charged ions, which remain on or adjacent to the surface of the metallite, can be repeated many times so that the density of 30 deuterons and lithons within the metallite can increase to whatever density can be accepted by the bulk metal in the interior of the metallite. The two electrodes create an electric field, and a separate accumulator structure 35 accumulates the deuterons and lithons.

This approach separates the positive ion accumulation function from the ion acceleration function so that the instantaneous negative electrode no longer is

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required to play a double role in both creating an electrical field and also accumulating the positive ion within its interior. Deuterons and lithons, once they enter the interior of a metallite without picking up an electron, behave as Bosons and act accordingly, as discussed above.

In a second ("surface mounted") embodiment, shown in a cutaway side view in Fig. 4, the deuteron/lithon permeable particulates 37 are held at the surface of solid dielectric, ceramic or insulating polymer material 39 that overlies an electrically non-conducting substrate 40 and are thereby exposed directly to the adjacent liquid and to the deuterium ions therein. Deuterons and lithons move to the surfaces of the metallites and pass into the interior of the metallite, and adjacent negative ions are attracted to the surface of the metallite in order to neutralize the net electrical charge on the metallite, as before. The choices of suitable dielectric materials, plastics, ceramics and insulative polymers for the polymer material 39 and substrate 40 are limited only by the requirements that the dielectric material should not degrade in the presence of the electrolyte and should not contaminate the electrolyte. In the first two embodiments, the thickness of the surface layer that holds the metallites is preferably 25 microns or greater. An area density of the metallites 37 in the range of 30-90 percent should be sufficient to attract an appreciable number of deuterium ions to the surfaces of the metallites over the area of each sheet.

In another embodiment, also shown in Fig. 1 (and in Figs. 5, 6 and 7), the electrodes 15 and 17 are not electrically insulated from the electrolyte, and deuterium atoms and molecules and oxygen atoms and molecules are alternately produced adjacent to, and combine with each other adjacent to, each of these electrodes as the voltage difference  $V_{12}(t)$  changes sign periodically. By this means the energy consumed in the electrolysis of  $D_2O$  into D and O is returned in the form of heat as the D

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and O recombine to form  $D_2O$ . This process can occur at both un-insulated electrodes or at one un-insulated electrode if the other electrode is insulated.

In a third embodiment, 41, shown in Fig. 5, two  
5 electrically insulated electrodes 43 and 45 of opposite polarity are spaced apart and positioned within a container 47 that contains a liquid 49 with a high purity heavy water therein. Alternatively, the electrodes are not insulated from the liquid, but are connected to an  
10 alternating voltage source through a large capacitor to minimize the impedance in series with the liquid. Preferably, such electrodes are covered with gold, silver or platinum. Deuterium ionization is again accomplished by adding an LiOD electrolyte to the liquid 49. The first  
15 electrode 43 may be rod-like, and the second electrode 45 may have a helical configuration or may consist of a collection of approximately concentric rings or a tubular cylinder with apertures therein, where the second electrode surrounds and is spaced apart from the first electrode  
20 in the liquid 49. The rod-like first electrode 43 is also radially surrounded by one or more approximately concentric, open mesh cylinders 51, 53, 55 that are made of solid dielectric, plastic, ceramic, polymeric or other similar electrically non-conducting material. The mesh  
25 cylinders 51, 53, 55, which are part of the deuteron/lithon accumulator, radially surround the first electrode 43, are surrounded by the second electrode 45, and are spaced apart from both electrodes. The non-conductive material of the mesh cylinders 51, 53, 55 serves as a  
30 matrix and has metallites (not shown in Fig. 5) mounted thereon at the surfaces of the matrix material. These surface-mounted metallites behave in a manner similar to the behavior of the surface-mounted metallites discussed in connection with the second embodiment above. A small  
35 region 51a of one of the cylinders 51, shown in greater detail in Fig. 5a, will consist of a first plurality of strands 51-1, 51-2, 51-3, 51-4 of electrically non-conducting material and a second plurality of transversely

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oriented strands 52-1, 52-2, 52-3, 52-4 of strands of this material. Metallites, shown as circles on Fig. 5a, are mounted on the surfaces of this matrix material and are thus exposed to deuterium ions that flow through the mesh apertures in response to the electrical field imposed by the electrodes 43 and 45 on Fig. 5. A voltage source 50 is connected between the two electrodes 43 and 45 to provide an alternating voltage difference  $V_{12}(t)$  such as shown in Figs. 2a, 2b or 2c, and a heat exchanger 57 is provided for energy conversion. As in the previous embodiments, the deuterons and lithons cannot pick up free electrons when the electrodes are insulated from liquid 49.

In a fourth embodiment 61, shown in Fig. 6, two electrically-insulated electrodes 63 and 65 of opposite polarity are spaced apart and positioned within a container 67 that contains a liquid 69 with a high purity heavy water therein. Alternatively, the electrodes are not insulated from the liquid, but are connected to an alternating voltage source through a large capacitor to minimize the impedance in series with the liquid. Preferably such electrodes are covered with gold, silver or platinum. The first electrode 63 may be rod-like, and the second electrode 65 may have a helical configuration or may consist of plurality of approximately concentric rings, or a tube with or without slits or apertures where the second electrode radially surrounds and is spaced apart from the first electrode in the liquid 69. The rod-like first electrode is also radially surrounded by one or more approximately concentric rings (not explicitly shown), each ring including a plurality of rods 71, 73, 75, 77, 79, 81, 83, 85, 87 that are oriented more or less parallel to the first electrode 63. Each of the rods 71, 73, ..., 87 is made of solid, electrically non-conducting material, such as a dielectric, plastic, ceramic or polymer material, and each such rod has a plurality of metallites mounted on its surface. The non-conducting rods 71, 73, ..., 87 are spaced sufficiently

close together that the gap or distance between two such adjacent rods in the same ring is of the order of 10-1000  $\mu\text{m}$ . The two electrodes 63 and 65 are connected by a voltage source 89 that provides an alternating voltage difference  $V_{12}(t)$  such as shown in Fig. 2a, 2b or 2c. As in the previous embodiments, the deuterons and lithons cannot pick up free electrons when the electrodes are insulated from liquid 69. A heat exchanger 90 is provided for energy conversion.

Fig. 6a illustrates in more detail a small region 81a on one of the non-conducting rods 81 with metallites (shown as small circles or spheres on Fig. 6a) surface mounted on the rod 81. The surface-mounted metallites behave in a manner similar to the behavior of the surface mounted metallites discussed in connection with the second embodiment above. The metallites are exposed to ions that flow around a non-conducting rod or between two such adjacent rods, in response to the electrical field imposed by the two electrodes.

In another embodiment 91 shown in Fig. 7, a container 93 holds a liquid 99 with high purity heavy water therein, and two electrically insulated electrodes 95 and 97 are immersed in the liquid within the container and spaced apart from one another as shown. The two electrodes 95 and 97, which are insulated from the liquid 99, are electrically connected by a voltage source 100 that provides a time varying voltage difference  $V_{12}(t)$  between the two electrodes. Alternatively, such electrodes are not insulated from the liquid, but are connected to an alternating voltage source through a large capacitor to minimize the impedance in series with the liquid. Preferably such electrodes are covered with gold, silver or platinum. A plurality of sheets or plates, several of which are shown as 101, 103, 105, 107, form the deuteron/lithon accumulator and are positioned between the two electrodes 95 and 97 so that these sheets are approximately parallel to one another and spaced apart from each other, with each sheet being oriented so

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that its surface orientation of the electrodes, relative to the surface orientation, ranges from approximately parallel to approximately orthogonal. A heat exchanger 110 is provided for energy conversion here. Each sheet 5 101, 103, 105, 107 may have a surface layer of an electrically non-conductive material, onto which metallites are deposited or adhered, as by deposition in a non-conducting thin layer. The manner of adhesion of small particulates onto the surface of a support substrate is also 10 known from the manufacture of fine abrasive sheets and saws. The absorption of deuterons and lithons into the particulate metallites, and neutralization of the electrical charge on each metallite, proceeds as discussed in connection with the prior procedure.

15 Deuterons and lithons may be produced by LiOD electrolyte-assisted ionization of the heavy water, which has a high concentration of deuterium atoms present in the form  $D_2O$ . The two electrodes in Figs. 1, 4, 5, 6 and 7 may be of conventional design and materials with an 20 approximately peak alternating current voltage difference  $-V_{ca}$  in the range -100 to -1 volts impressed across the liquid and a higher peak voltage across the electrodes owing to the extra voltage drop across the capacitance at the two electrodes when they are insulated from the 25 liquid.

Reilly and Sandrock have discussed the use of metal hydrides as a storage medium for hydrogen and its isotopes in "Hydrogen Storage in Metal Hydrides", Scientific American (February 1980), pp. 119-130. These authors have noted that materials such as those set forth 30 above for the surface layer of the screen have a higher hydrogen storage or acceptance capacity than an equal volume of liquid hydrogen or gaseous hydrogen maintained at a pressure of 100 atmospheres. Theoretically, palladium, which has characteristic valences of +2 and +4, 35 could accept and store two to four times as many deuterium atoms or ions as the number of palladium atoms present. However, a more realistic ratio of the maximum

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number of deuterium atoms or ions present to the number of palladium atoms present may be about 0.6. The numerical density of solid palladium is about  $6.75 \times 10^{22}$  Pd atoms  $\text{cm}^{-3}$  so that a realizable average density of deuterium atoms bound into a Pd-based lattice could be about  $4 \times 10^{22}$  D atoms or ions  $\text{cm}^{-3}$ . This density of deuterons within the lattice has the potential for deuteron-related fusion reactions.

Jones et al. in "Observation of Cold Nuclear Fusion in Condensed Matter", Nature (1989), reports on detection of neutrons resulting from deuterium-deuterium fusion in a metallic titanium or palladium electrode. These workers used an electrolyte as a mixture of 160 grams of deuterium oxide  $\text{D}_2\text{O}$  plus 0.2 grams of each of the metal salts  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ,  $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ ,  $\text{PdCl}_2$ ,  $\text{CaCO}_3$ ,  $\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$ ,  $\text{NaSO}_4 \cdot 10\text{H}_2\text{O}$ ,  $\text{CaH}_4(\text{PO}_4)_2 \cdot \text{H}_2\text{O}$ ,  $\text{TiOSO}_4 \cdot \text{H}_2\text{SO}_4 \cdot 8\text{H}_2\text{O}$ . The pH of the electrolyte was adjusted to less than 3.0 using the addition of  $\text{HNO}_3$ . After electrolysis was begun, oxygen bubbles were observed to form immediately at the anode. However, hydrogen or deuterium bubbles were observed to form at the negative electrode (Pd or Ti) only after many minutes of electrolysis, suggesting the rapid absorption of deuterium into this electrode initially. No generation of excess enthalpy was reported.

Fleischmann and Pons, Electrochemically Induced Nuclear Fusion of Deuterium, J. Electroanal. Chem. Vol. 261 (1989), p. 301, and at The First Annual Conference on Cold Fusion, March 28-31, 1990, report on the generation of thermal energy in palladium in an electrolysis cell using heavy water, a palladium cathode, a platinum helix anode and a 0.1M LiOD electrolyte solution. Generation of excess enthalpy was reported.

In the Fleischmann-Pons cell the only electrodes are a palladium cathode and a platinum anode. The cathode plays a dual role in both accumulating the deuterons and lithons and in converting the deuterons to a deuterium gas.

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The invention disclosed herein physically separates the accumulation of the deuterons and lithons from the electrolysis function, whereas in the prior art these activities both take place at the cathode. The invention  
5 includes a further step of suppressing or eliminating the electrolysis process. The invention also takes the step of providing a palladium accumulator which does not provide free electrons to the lithium ions. Thus the lithium ions do not deposit on the accumulator to the extent  
10 they do in the prior art.

Energy loss through electrolysis of the heavy water into deuterium and oxygen gases, as in the prior art, is suppressed here by using insulated electrodes which deny the ions access to free electrons at the electrodes or in another embodiment the gases are created but  
15 recombine to return energy to the liquid in the form of heat. Also, through using of an alternating current voltage, the deuterons and lithons pass near the accumulator a number of times thereby increasing the probability  
20 of interception and absorption on the accumulator.

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## Claims

1. Apparatus for production of energy through accumulation of deuterons and lithons, the apparatus comprising:

a container containing primarily high purity liquid heavy water and an electrolyte containing  $\text{Li}^6\text{OD}$  in the liquid;

a first electrically insulated electrode immersed in the heavy water;

a second electrically insulated electrode, immersed in the liquid and spaced apart from the first electrode;

an alternating voltage source, connected between the first and second electrodes, to supply an alternating voltage difference between the two electrodes to cause the deuterium ions to alternately move to the first electrode, and to the second electrode;

an accumulator, immersed in the liquid at a position lying between and spaced apart from the two electrodes, to intercept a fraction of the deuterons and lithons during each pass through the accumulator as both ions move alternately toward the first electrode and toward the second electrode, where the accumulator includes deuteron permeable and lithon permeable particulates supported in an electrically non-conducting matrix layer on an electrically non-conductive support structure; and

energy removal means for removing thermal energy from the accumulator.

2. The apparatus of claim 1 wherein said particulates are drawn from a class of materials consisting of palladium, palladium composite or palladium alloy.

3. The apparatus of claim 1, wherein said particulate material includes at least two different materials, each being permeable by deuterons and by lithons.

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4. The apparatus of claim 1 wherein each of said particulates has a diameter less than ten millimeters.

5. The apparatus of claim 1, wherein said electrodes insulate said alternating voltage source from the liquid by means of a capacitor positioned between said electrode and said voltage source.

6. The apparatus of claim 1 wherein said matrix layer material is drawn from the class consisting of a gelatin matrix and a polyvinyl alcohol matrix.

7. The apparatus of claim 1 wherein said accumulator comprises parallel, spaced apart annular disks or sheets with one of said electrodes passing through the disks or sheets.

8. The apparatus of claim 1 wherein said accumulator comprises stacked, parallel, spaced apart plates with said electrodes being positioned near opposed sides of the plates.

9. The apparatus of claim 1 wherein said energy removal means comprises a heat exchanger.

10. The apparatus of claim 1 wherein said accumulator comprises a thin member with two opposed major surfaces, with said particulates being positioned on at least one of the opposed major surfaces.

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11. The apparatus of claim 1, wherein said accumulator radially surrounds said first electrode.

12. The apparatus of claim 11, wherein said support structure comprises a helical rod.

13. The apparatus of claim 11, wherein said support structure comprises a mesh cage.

14. The apparatus of claim 1, wherein said support structure is a plurality of parallel rods, all oriented approximately perpendicular to a plane, with the intersection of each rod with the plane lying along a closed convex curve in that plane that radially surrounds the intersection of said first electrode with the plane.

15. The apparatus of claim 11, wherein said second electrode radially surrounds said accumulator.

16. The apparatus of claim 15, wherein said second electrode comprises a helical rod of electrically conducting material.

17. The apparatus of claim 15, wherein said second electrode comprises a mesh cage.

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18. Apparatus for production of energy through accumulation of deuterons and lithons, the apparatus comprising:

a container containing primarily high purity liquid heavy water and an electrolyte containing  $\text{Li}^6\text{OD}$ ;

a first electrically insulated electrode immersed in the liquid and spaced apart from the container;

a second electrically insulated electrode immersed in the liquid and spaced apart from the container and from the first electrode;

a plurality of spaced apart electrically non-conductive sheets immersed in the liquid at positions between the first and second electrodes, each sheet having a surface layer that includes particulates of a deuteron permeable and lithon permeable material, the sheets being oriented approximately parallel to one another;

an alternating voltage source, connected between the first and second electrodes, to supply an alternating voltage difference between the two electrodes sufficient to establish an alternating ion flow between the sheets toward one or the other of the electrodes; and

removal means for removing thermal energy from one or more of the sheets.

19. The apparatus of claim 18, wherein said particulates are drawn from a class of materials consisting of palladium, palladium composite or palladium alloy.

20. The apparatus of claim 18, wherein said particulate material includes at least two different materials, each being permeable by deuterons and by lithons.

21. The apparatus of claim 18, wherein each of said particulates has a diameter less than ten millimeters.

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22. The apparatus of claim 18, wherein said electrodes insulate said alternating voltage source from the liquid by means of a capacitor positioned between said electrode and said voltage source.

23. The apparatus of claim 18, wherein said energy removal means comprises a heat exchanger.

24. The apparatus of claim 18, wherein at least one of said sheets comprises a thin member with two opposed major surfaces, with said particulates being positioned on at least one of the opposed major surfaces.

25. A method for production of energy through accumulation of deuterons and lithons, the method comprising the steps of:

- providing a container containing primarily liquid heavy water;

- ionizing the heavy water with an electrolyte containing  $\text{Li}^6\text{OD}$  in the liquid;

- providing two electrodes, spaced apart and immersed in the liquid;

- providing an alternating voltage source connected to the first and second electrodes to cause deuterium ions to move back and forth between the two electrodes as the voltage between them alternates;

- providing a matrix of suspended deuteron absorbing and lithon absorbing metal particles immersed in the liquid at a position between the two electrodes; and

- providing energy removal means for removing thermal energy from the suspended particles in the matrix,

whereby deuterons and lithons are accumulated at high density in the matrix and combine to produce energy.

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26. The method of claim 25, further comprising the step of choosing a capacitor to insert between said electrodes and said liquid to insulate said voltage source from said liquid.

27. The method of claim 25, further comprising the step of choosing said particle material from a class of materials consisting of palladium, palladium composite or palladium alloy.

28. Apparatus for production of energy through accumulation of deuterons and lithons, the apparatus comprising:

- a container containing primarily high purity liquid heavy water and an electrolyte containing  $\text{Li}^6\text{OD}$  in the liquid;

- a first electrode immersed in the liquid and spaced apart from the container;

- a second electrode immersed in the liquid and spaced apart from the container and from the first electrode, where at most one of the first and second electrodes is electrically insulated from the liquid;

- a plurality of spaced apart electrically non-conductive sheets immersed in the liquid at positions between the first and second electrodes, each sheet having a surface layer that includes particulates of a deuteron permeable and lithon permeable material, the sheets being oriented approximately parallel to one another;

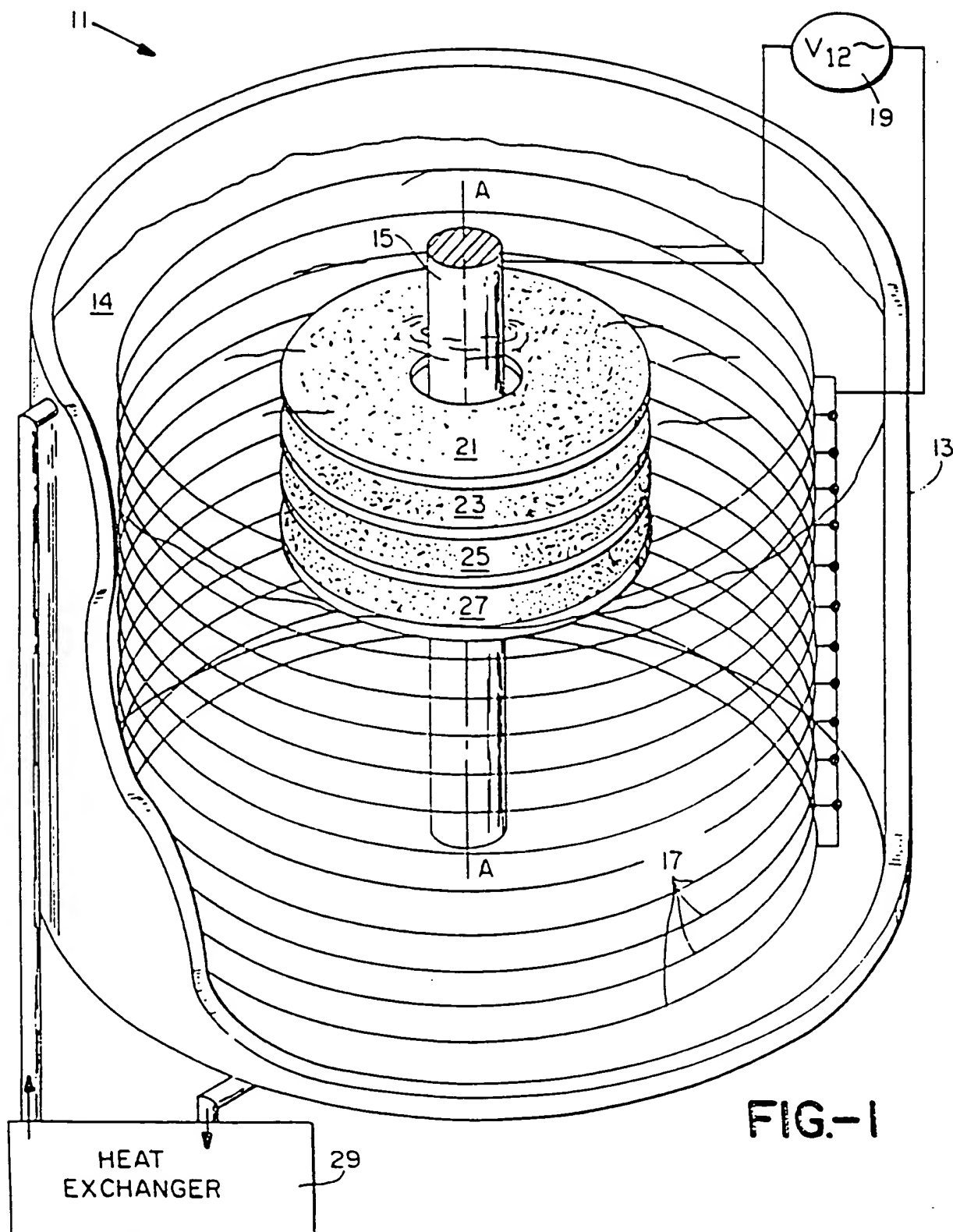
- an alternating voltage source, connected between the first and second electrodes, to supply an alternating voltage difference between the two electrodes sufficient to establish an alternating ion flow between the sheets toward one or the other of the electrodes; and

- removal means for removing thermal energy from one or more of the sheets.

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29. The apparatus of claim 28, wherein said particulates are drawn from a class of materials consisting of palladium, palladium composite or palladium alloy.

30. The apparatus of claim 28, wherein said particulate material includes at least two different materials, each being permeable by deuterons and by lithons.



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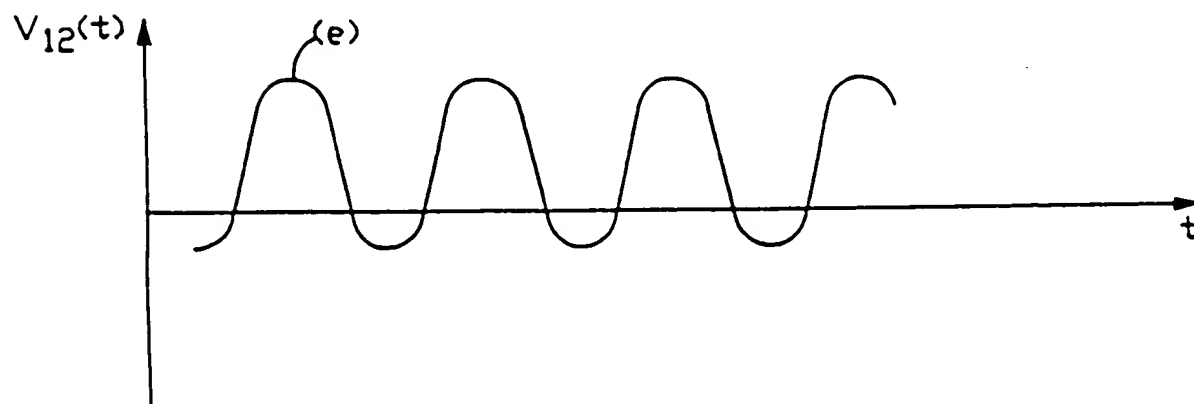
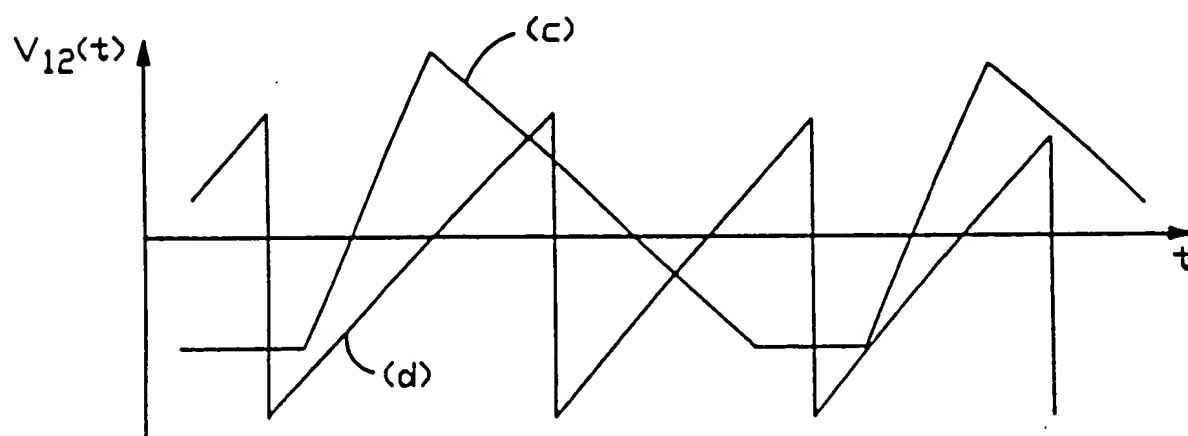
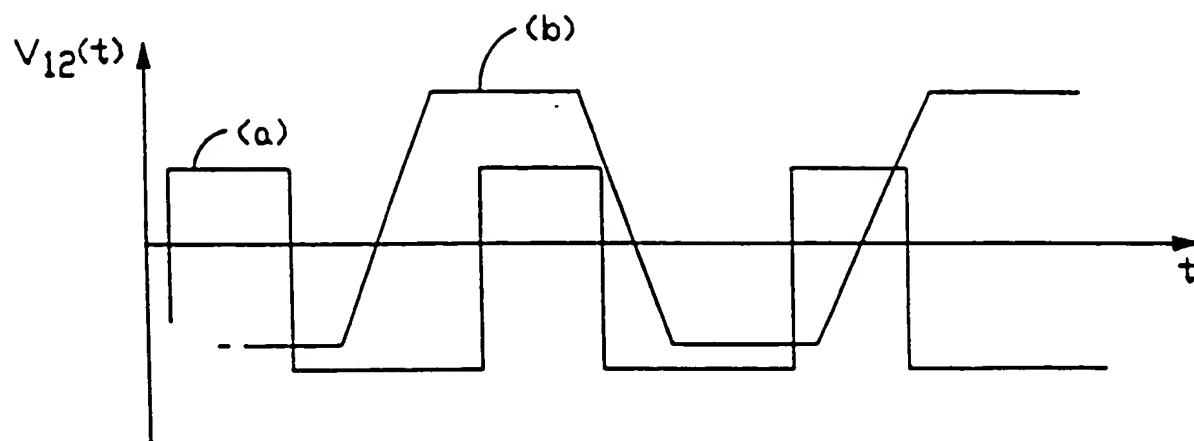


FIG.-2

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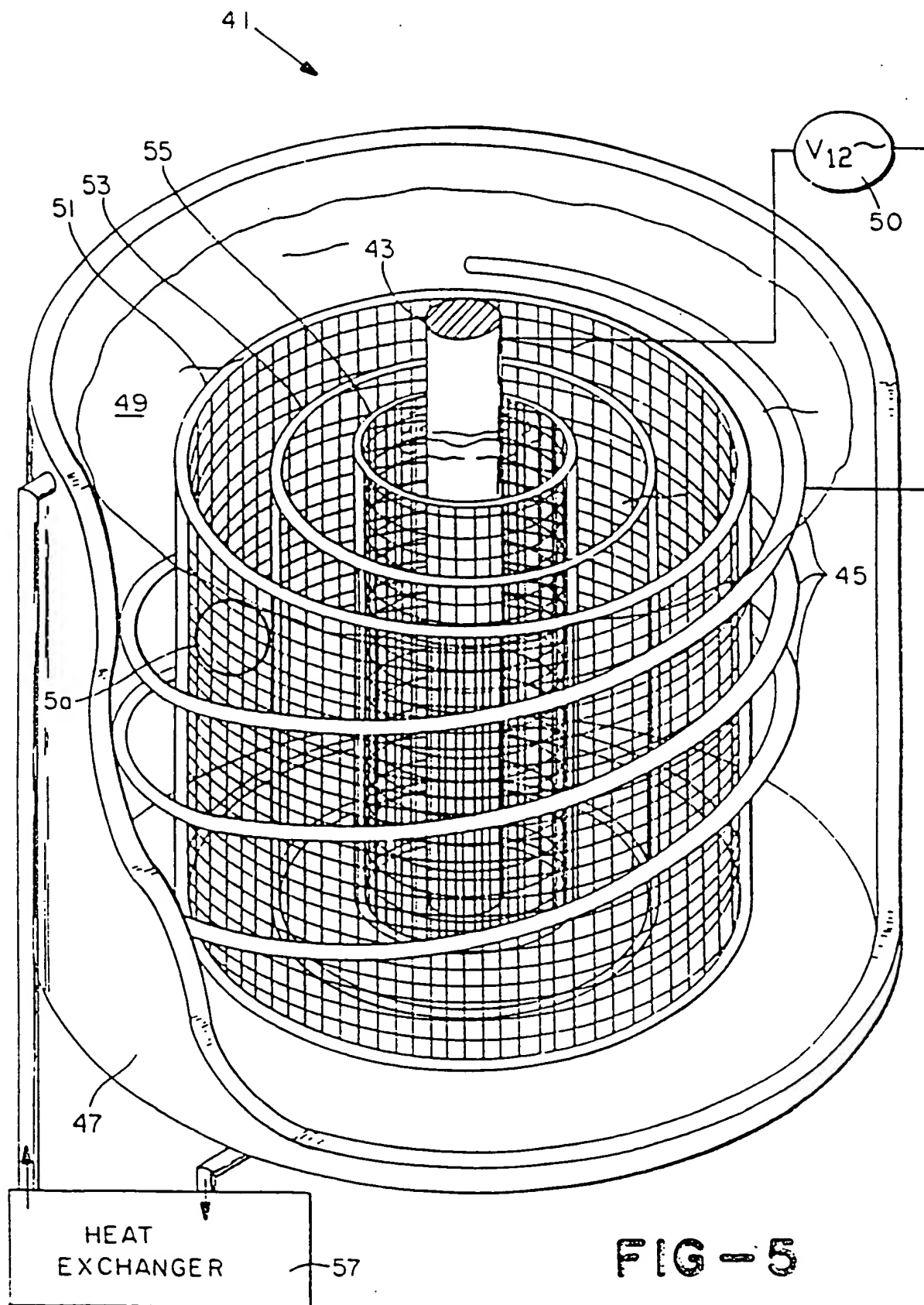
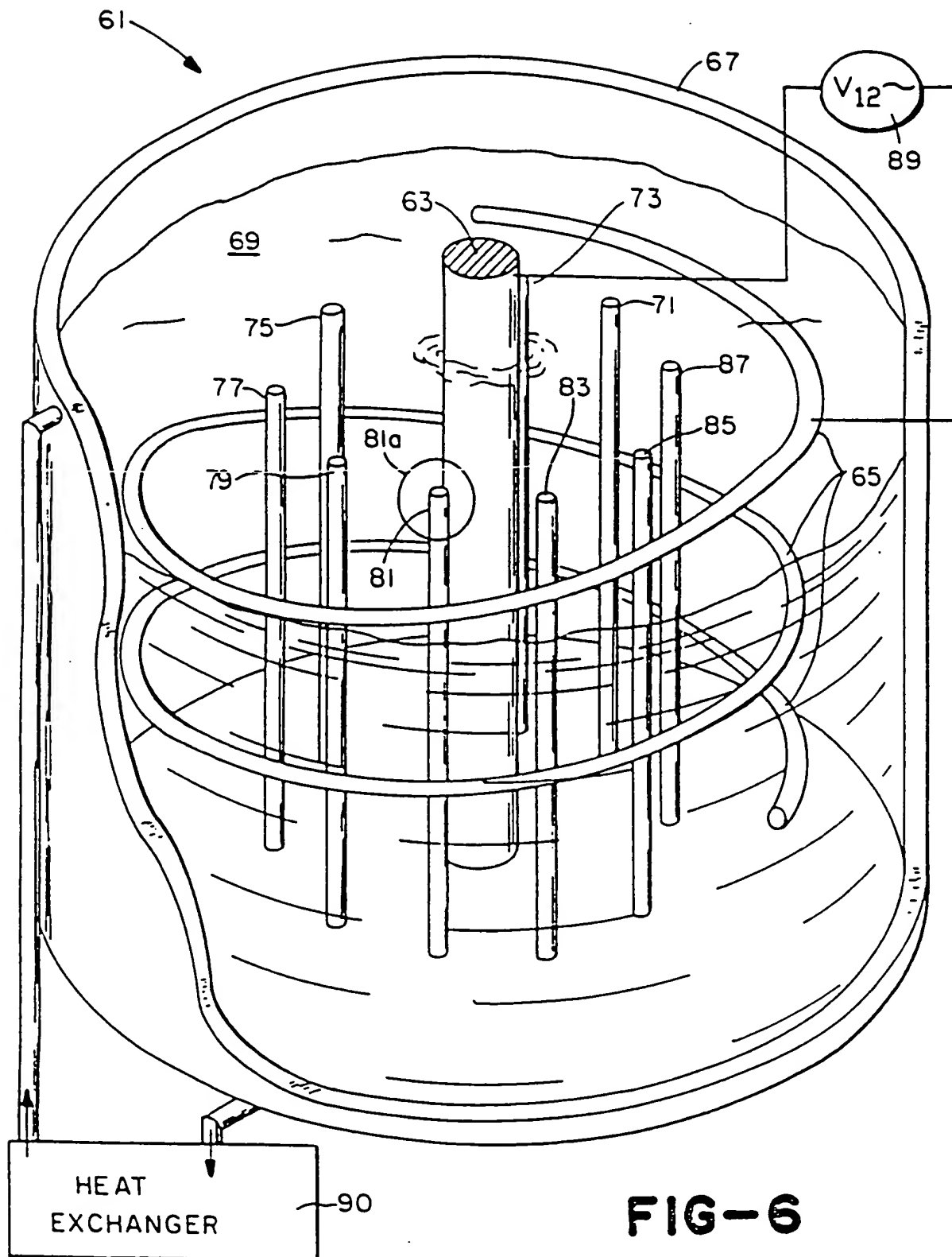
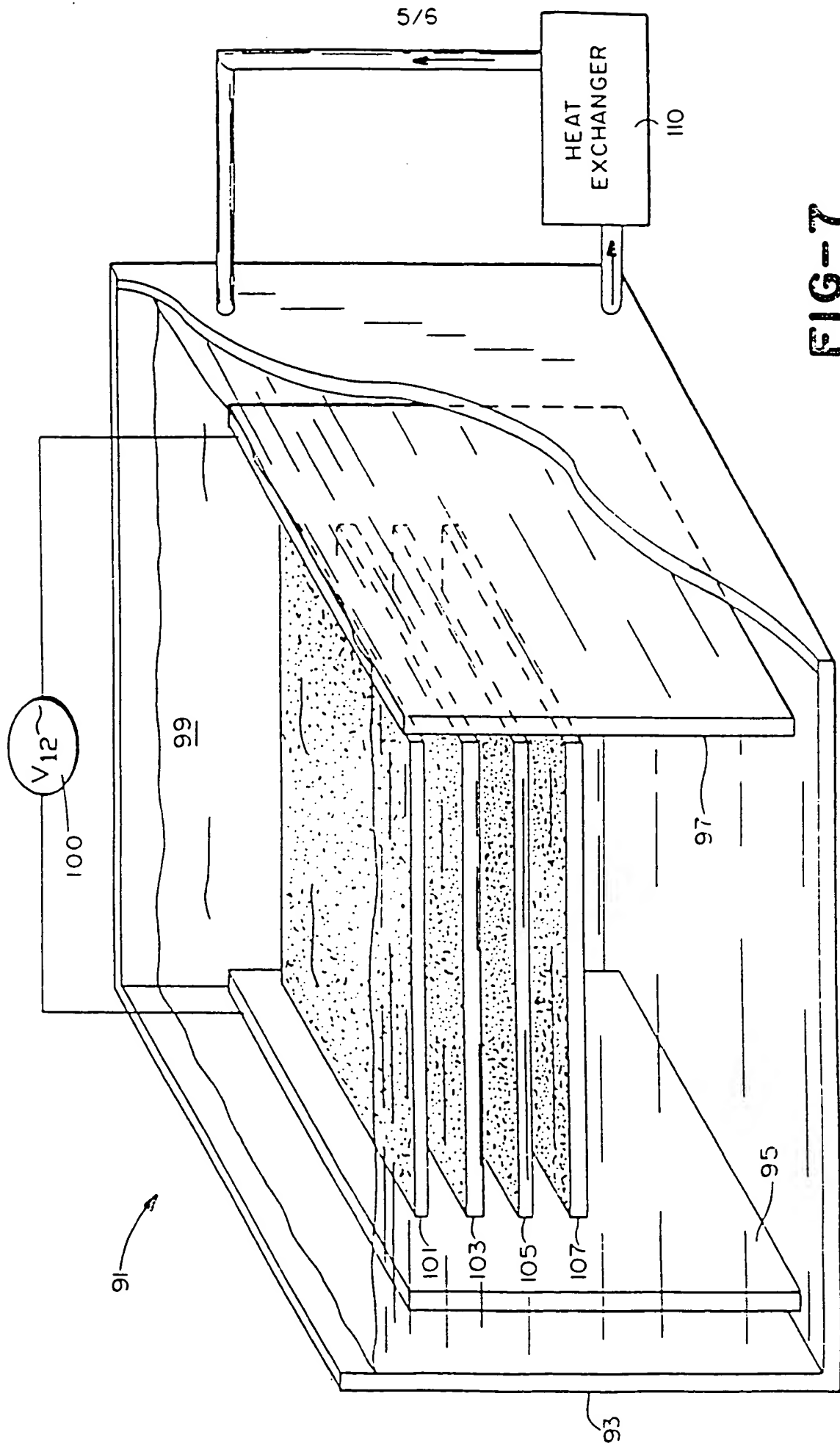
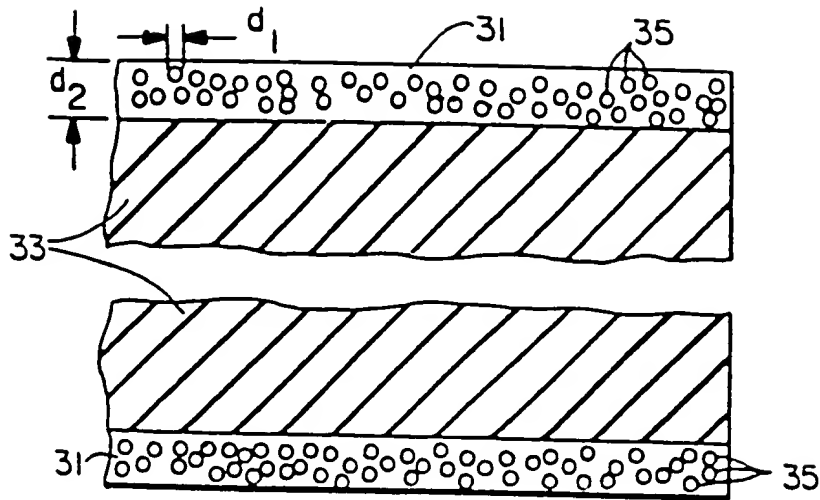
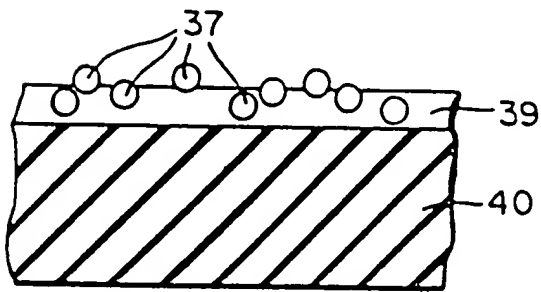
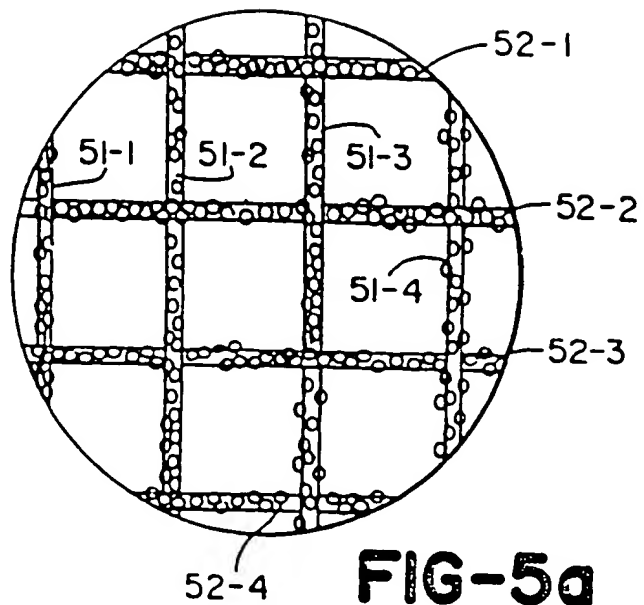
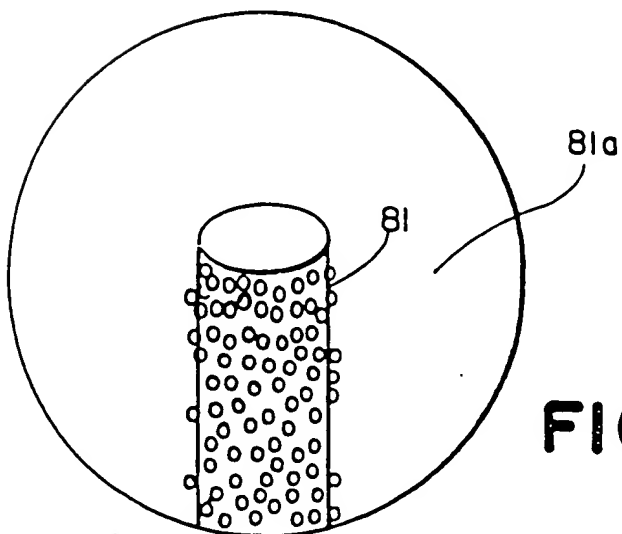


FIG-5





**FIG-3****FIG-4****FIG-5a****FIG-6a**

International Application No. PCT/US91/03280

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) <sup>6</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): G21B 1/00

U.S.CI.: 376/100

## II. FIELDS SEARCHED

Minimum Documentation Searched <sup>7</sup>

Classification System	Classification Symbols
U.S. CI.	376/100, 146; 204/Dig. 8, 204/129, 243R, 252, 262, 272, 274, 290R, 290F, 295, 296

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup>

Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
Y	J. Electroanal. Chem., vol. 261, issued 10 April 1989, Fleischmann et al., see pages 301-308.	1-7, 9, 10 18-30
L	Nature, vol. 344, issued 29 March 1990, Salamon et al., pages 401-405, (cited as casting doubt on the obtainment of electrochemically induced nuclear fusion).	
L	ORNL/FTR -3341, dated 31 July 1989, Cooke, see pages 3-5, (cited as casting doubt on the obtainment of electrochemically induced nuclear fusion).	
Y	The Palladium Hydrogen System, dated 1967, author F. A. Lewis, Academic Press London London - New York, see pages 3-6, 11, 12, 37, 38, 129-137.	1-7, 9, 10 18-20
Y	US, A, 3,377,265 (CAESAR) 09 April 1968 See col. 3 lines 63+.	1-7, 9, 10 18-24, 28-30

<sup>10</sup> Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"Δ" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search

Date of Mailing of this International Search Report

13 August 1991

27 AUG 1991

International Searching Authority

Signature of Authorized Officer

ISA/US

Harvey E. Behrend

## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

Y	GB, A, 1,338,379 (BAILEY) 21 November 1973 See pages 2 lines 31+.	1-7, 9, 10 18-30
Y	US, A, 3,113,080 (ANDRUS) 03 December 1963	1-7, 9, 10 18-30
Y	US, A, 3,193,485 (VINCENT) 06 July 1965 See Fig. 5 and col. 1, lines 63+	5, 22, 26
Y	US, A, 4,869,790 (CHARLES ET AL.) 26 September 1989, see Fig. 2 and col. 3 lines 16+	7

V ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE<sup>1</sup>

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1 ☐ Claim numbers \_\_\_\_\_ because they relate to subject matter not required to be searched by this Authority, namely:

2 ☐ Claim numbers \_\_\_\_\_ because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out by, specifically:

3 ☐ Claim numbers \_\_\_\_\_ because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6 4(a).

VI ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING<sup>2</sup>

This International Searching Authority found multiple inventions in this international application as follows:

- I. The embodiment of Fig. 1 (claims 1-7, 9, 10, 18-30).
- II. The embodiment of Fig. 5 (claims 1-6, 9, 10, 11, 13, 15-17, 25-27).
- III. The embodiment of Fig. 6 (claims 1-6, 9-11, 14-17, 25-27).
- IV. The embodiment of Fig. 7 (claims 1-6, 8-10, 18-30)

1 ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2 ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3 ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

1-7, 9, 10, 18-30

4 ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

## Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

## III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
Y	US, A, 4,541,905 (KUWANA) 17 September 1985 (see Fig. 1).	6
Y	US, A, 4,235,748 (BERCHIELLI) 25 November 1980 see the abstract	6
Y	Physical Review Letters, vol. 62, No. 25, 19 June 1989, Ziegler et al., pages 2929- 2932, see particularly the lower half of the first column on page 2930.	1-7,9,10

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